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August 13, 2001
TWP: MHECECAYX
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TO: M. Ewert /EC2

VIA: J. Keener /C70
K. Lange /C70

FROM: Gregg Weaver /C70
Cheryl Brown /C70
Jannivine Yeh /C70

SUBJECT: Latest Advanced Life Support Developments

This report is meant to satisfy Requirement 19 outlined in ST MHECECAYS. This requirement states

> "Report on latest ALS [Advanced Life Support] developments. Attend a technical interchange meeting with ALS experts and gather information relevant to the ALS technology areas (Air, Biomass, Food, Thermal, Water and Waste) and to systems analyses."

INTRODUCTION

Cheryl Brown, Jannivine Yeh, and Gregg Weaver attended the 31st International Conference on Environmental Systems (ICES) in Orlando, Florida, during July 9-12, 2001. More than 50 sessions provided a venue for members of the international community to present more than 250 papers relating to the following categories[1][1]:

- Exploration Missions/Advanced Life Support
- Life Sciences & Astrobiology
- Spacecraft ECLSS (Environmental Control and Life Support Systems)
- ECLS (Environmental Control and Life Support) Technology
- Extra Vehicular Activity/Robotics
- Simulation Software/Analysis & Modeling
- Spacecraft and Aircraft Thermal Control
- Thermal Control Technology and Testing
- Architecture and Human Factors

This 4-day conference provided the attendees ample opportunity to gather information relevant to all ALS technology areas and to meet with ALS experts. In addition, the authors of this paper presented the following:

[1] Numbers in brackets refer to references listed at the end of this document.

- *BIO-Plex Thermal Control System Design*; authored by Richard D. Morton/LMSO, Imelda C. Stambaugh/LMSO, Gregg S. Weaver/LMSO, Michael K. Ewert/JSC, and Kathryn Hurlbert/JSC; presented by Gregg S. Weaver/LMSO.
- *Thermal Analysis of Compressible Gaseous Nitrogen Flow of X-38 Pressure Control System for First Mission Phase*; authored by Michael Y. Zhang/LMSO, Kambiz K. Andish/LMSO, John F. Keener/LMSO, and Charles W. Dingell/JSC; presented by Gregg Weaver/LMSO.
- *Estimating Plant Growth Area with the Biomass Production Chamber Sizing Model*; authored by Cheryl B. Brown/LMSO and Wen-Ching Lee/HEI; presented by Cheryl B. Brown/LMSO.
- *Advanced Life Support Sizing Analysis Tool (ALSSAT) Using Microsoft ® Excel*; authored by H. Y. (Jannivine) Yeh/LMSO, Frank F. Jeng/LMSO, Cheryl B. Brown/LMSO, Chin H. Lin/JSC, and Michael K. Ewert/JSC; presented by Jannivine Yeh/LMSO.

Additionally, each attendee received both a hardcopy booklet listing the abstracts of every paper submitted for the conference[2], and a compact disk containing PDF versions of each paper[3]. Each ICES paper contains author contact information so that readers may obtain additional information.

The conference also afforded attendees the opportunity to have discussions with colleagues from other NASA centers. Advanced Life Support Sizing Analysis Tool (ALSSAT) peer review committee meetings were held on 07/11/01 and 07/12/01 between Jannivine Yeh/LMSO, Cheryl B. Brown/LMSO, Julie Levri/NASA Ames Research Center, and Alan Drysdale/Boeing/KSC. The purpose of these meetings was to continue the ALSSAT peer review discussions started on 07/03/01. The applicability of ALSSAT within the ALS community and future considerations for tool development were discussed in detail. Suggestions and comments expressed by Dr. Drysdale and Ms. Levri were collected and will be among the recommendations for tool improvement provided to NASA for FY02.

This report will summarize key ALS developments discussed at the conference, including notable ICES publications. More in-depth information can be found by referring to [2] or [3], or by contacting the respective authors of the ICES papers.

CONFERENCE HIGHLIGHTS/RELEVANT PUBLICATIONS

The authors of this paper were able to separate at the conference and attend different lectures. Thus, they were able to cover a significant number of the presentations and are able to relate many conference highlights on a variety of topics that are worthy of mention. These are listed numerically below with a brief synopsis of each topic. Because not everyone will be interested in every topic, the reader is encouraged to refer to the enclosed matrix to determine which conference presentations and papers are of interest, and then skip to the corresponding entry in the list of highlights that follows.

Placement of the matrix indicators is somewhat subjective in nature and may vary according to individual interpretation. Although every attempt has been made to ensure the accuracy and

completeness of the matrix, indicator omissions may be present. The authors of this document regret any oversights.

Highlight	Topic																			
	Plant growth	Nutrients/nutrient delivery	Lighting	Modeling/analysis	Mass balance	Human testing	Physiology	ECLSS - food/nutrition	ECLSS - water	ECLSS - air	ECLSS - waste	Thermal control	Humidity control	Data acquisition/control	Mars Missions	Space suits/PLSs	Loop heat pipes	ISS	Refrigeration technology	Equivalent System Mass (ESM)
1	✓			✓	✓															
2					✓	✓		✓	✓	✓	✓									
3	✓											✓	✓	✓						
4															✓	✓				
5	✓	✓						✓						✓						
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Highlight	Topic																			
	Plant growth	Nutrients/nutrient delivery	Lighting	Modeling/analysis	Mass balance	Human testing	Physiology	ECLSS - food/nutrition	ECLSS - water	ECLSS - air	ECLSS - waste	Thermal control	Humidity control	Data acquisition/control	Mars Missions	Space suits/PLSs	Loop heat pipes	ISS	Refrigeration technology	Equivalent System Mass (ESM)
30				✓		✓					✓				✓					
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61				✓						✓								✓		

1) *Simulation to Support an Integration Test Project of Closed Ecology Experiment Facilities (CEEF),* paper 2001-01-2130, discusses test results on open mode simulations performed at the Institute for Environmental Sciences in Tokyo using the Closed Plant Experiment Facility (CPEF). The CPEF is one of three sections of the CEEF. It was used to conduct integration testing on the CEEF material circulation system for sequential cultivation of ten food crops. Water and carbon dioxide (CO_2) were supplied to the chamber, and the CO_2 level was kept at a nighttime level of 2000 ppm. A mathematical plant growth mass balance model is discussed in this paper using the assumption of a hydroponic growth medium for nutrient delivery.
2) *Data on Human Mass Balance Obtained in a Manned Test of Regenerative Life Support Systems,* paper 2001-01-2131, presents a human material balance numerical model based on data measurements taken during a 48-hour test of a regenerative ECLSS. Data measured includes the liquid and food intake, urine, feces, latent respiration, perspiration, and metabolic trace gases of five individuals living and working in an isolation chamber. An O_2 requirement of 840 g/p/day and CO_2 generation rate of 1000 g/p/day were used as a basis for this model.
3) A presentation that seemed relevant to work underway at JSC was *Science Accommodations in the Biomass Production System*, paper 2001-01-2231. This presentation/paper discussed the development of a payload for the space shuttle or space station that is composed of plant growth chambers with independent temperature and humidity control. Carbon dioxide levels, nutrient solutions, and light levels were also controlled to grow dwarf wheat and brassica. The paper discusses the operation and control of the system.
4) *Advanced, Lightweight, Space Suit Primary Life Support System for Mars Exploration,* paper 2001-01-2167, discusses attempts by Hamilton Sundstrand to reduce reliance on expendables in developing an advanced space suit to support a Mars mission.
5) *An Evaluation of a Fibrous Ion Exchange Resin Substrate for the Provision of Nutrients to Wheat Growing on a Porous Tube Nutrient Delivery System*, paper 2001-01-2177, was presented by Georgiana Tynes/Dynamic Corp. This paper evaluates a Fibrous Ion Exchange Resin Substrate (FIERS) in terms of its ability to provide nutrients to hydroponically grown wheat cultivars on a porous tube nutrient delivery system. The FIERS nutrient system was compared to the commonly used Hoagland's solution and was found to provide all nutritional needs of wheat seeds grown through to seed production.
6) Orbital Technologies discusses the use of heat pulse probes, a microcontroller, and data acquisition software to determine moisture levels and root zone temperature in plant growth units in their paper 2001-01-2178, *A Microprocessor Based Soil Moisture Sensor System for Space Based Plant Growth Units.* This technology has been investigated as a means to provide a uniform growth environment to plants in microgravity conditions and to regulate nutrient delivery systems in said conditions.
7) The research and testing of liquid/gas phase control in biomass production systems (BPSs) is being explored by Orbital Technologies and was presented in paper 2001-01-2179, *Fluid Handling and Maintenance Experiment Capabilities*. The authors indicate that the Fluid Handling and Maintenance Experiment's (FHAME's) current design will lessen the unknown factors of fluid management in microgravity and can be modified to accommodate other experimental conditions. Designed to control space-based fluid handling systems, including nutrient delivery systems and humidity control systems, FHAME can also quantify liquid and gas flows in a BPS.
8) *Evapotranspiration and Photosynthesis Characteristics of Two Wheat Cultivars Measured in the Biomass Production System*, paper 2001-01-2180, discusses a 24-day test conducted under closed conditions in a biomass production system for the purpose of identifying

optimum times during the life cycle of wheat for obtaining evapotranspiration and photosynthesis rates. Dr. Gary Stutte/Dynamac Corp. presented data for the PESTO (Photosynthesis Experiment System Testing and Operation) experiment consisting of CO_2 and light response curves gathered on apogee and super dwarf wheat cultivars. The reliability of using gas exchange data to measure plant growth is evaluated using lyophilization techniques.

9) Anna-Lisa Paul/University of Florida presented a paper entitled *Transgenic Plant Biomonitors: Stress Gene Biocompatiblity Evaluation of the Plant Growth Facility for PGIM-01,* paper 2001-01-2181. The paper explores the plant stress effects of wilting and gene expression as well as the use of a genetically engineered reporter gene system called Transgenic Arabidopsis Gene Expression System (TAGES) in simulated flight conditions similar to those experienced in flight STS-93.
10) *Aspects on Plant Growth Using EMCS Hardware,* paper 2001-01-2182, discusses a breadboard test for use in the European Modular Cultivation System (EMCS) to determine whether its major components are optimal for space experiments with plant material. The major components involved were the experiment containers, the illumination test elements for both white and white+red LED, gas chromatography equipment used for chemical identification and quantification of potentially volatile components, humidity control, and water supply test elements. Plant growth studies were conducted on cress seedlings grown on soil, sponge, glass wool, and rock wool growth media. The use of filters in the EMCS was tested for efficiency, capacity, microbial grow-through, and filter failure as it related to microbial contamination in the water filtration system.
11) Numerous presentations were given relating to loop heat pipes and their use in thermal control and heat rejection; for example, *Investigation of Low Operation in a Loop Heat Pipe*, paper 2001-01-2192. This paper stresses the importance of accurately estimating the void fraction in a heat pipe before developing a suitable analytical model. Also of interest was *Mathematical Modeling for Predicting Steady State and Transient Characteristics of Reservoir Embedded Looped Heat Pipe (RELHP)*, paper 2001-01-2239.
12) *The Crew Refrigerator/Freezer Rack for the International Space Station*, paper 2001-01-2223, discusses improvements and analytical results regarding the thermal performance of the space station refrigerator/freezer rack.
13) *Considerations in the Development of Habitats for the Support of Live Rodents on the International Space Station,* paper 2001-01-2228, outlines the requirements, system design, and functionality of the Advanced Animal Habitat-Centrifuge (AAH-C) that is being developed for use on the ISS to study the effects of microgravity on rodents. This paper discusses habitat capabilities and requirements, developmental challenges, considerations for controlled rodent living conditions, science and animal welfare considerations, and engineering considerations critical to the AAH-C.
14) The effect of gravity on single-celled organisms was studied and findings reported in *Space Life Support from the Cellular Perspective,* paper 2001-01-2229. To overcome the lack of natural convection in microgravity, a perfusion-based (forced convection) Cell Culture Unit is used to house Cell Specimen Chambers (CSC). Use of four thermally-isolated CSC's allows control of temperature, humidity, and pH in four separate thermal environments. Of interest were the findings relating to the necessity for uniform gas and nutrient exchange in plant and mammalian cells in various thermal environments.
15) Gravitational influences on the biology and chemistry of plants are being studied by Orbital Technologies. Findings are presented in paper 2001-01-2230, *Plant Research Unit, Program Overview.* The Plant Research Unit (PRU) is housed in a modular unit that allows simulation of gravitational variations ranging from 0.01-g to 2-g. The PRU is used to study

the control and automation of plant growth chamber parameters, including temperature, humidity, atmospheric composition, lighting, and three nutrient delivery systems (solid substrate, semi-solid substrate, and fully fluid systems).

16) Limitations inherent to the Ideal Gas Law are discussed in paper 2001-01-2251, *Two-Parameter Equations of State for ARPCS Applications.* According to Richard Chu/HEI, an error of up to 0.7% is present in the Ideal Gas Law. When actual data is lacking and the use of analytical tools is required, Dr. Chu proposes the use of two-parameter equations of state (EOS) such as the Peng-Robinson EOS and the Redlich-Kwong EOS. Applicability for several ECLS subsystems in the depress/repress/compression of air and gases is presented in this paper, which states that the error present in the Ideal Gas Law can be reduced to within a 0.01% range through use of these two-parameter equations of state.
17) *ARPCS2AT2_STATION: A Tool for Atmospheric Pressure and Composition Control Analysis*, paper 2001-01-2252, summarized Sharon Lafuse's/JSC and Richard Chu's/HEI work on a programming tool to help predict the chemical composition of the air in a multi-chamber environment. This tool, somewhat reminiscent of G189A, has an easy-to-use graphical interface and is expandable to aid in the modeling of new ECLSS components.
18) *Pre-Flight Analysis and Post-Flight Assessment of ISS Mission 2R*, paper 2001-01-2254, gives an overview of Boeing's SINDA/FLUINT model used to predict O_2, CO_2, temperature, and humidity within the space station chambers. Comparisons with flight data were made.
19) Several presentations discussed research involving the 41-Node Man model (developed by Lockheed). These presentations included *Modeling the Human Sweat Thermal Dynamics*, paper 2001-01-2266, and *Thermal Comfort Control of an Advanced Space Suit*, paper 2001-02-2268, among others. These presentations discussed studies that made extensive use of the 41-Node Man model to predict thermal behavior of the crew during missions.
20) *Utilization of Recovered Inorganic Nutrients from Composted Fresh or Oven-dried Inedible Plant Biomass for Supporting Growth of Wheat in a BLSS*, paper 2001-01-2273, compares the crop growth of hydroponically grown apogee wheat plants using a leachate from composted fresh inedible wheat biomass to those found when using composted oven-dried biomass as a nutrient replenishment solution. Filtered and unfiltered leachates were tested by Dynamac Corp. and the Florida Institute of Technology. Results suggest that use of oven-dried composted wheat biomass causes significant reduction in all growth parameters when compared to the Hoagland's control solution and that unfiltered compost leachate may be beneficial to plant growth.
21) *Using Mass Balance Techniques to Manage Nutrition of Hydroponically-Grown Sweetpotato [Ipomoea Batetas (L.) Lam]*, paper 2001-01-2274, as presented by Desmond Mortley/Tuskegee University, discusses the principle of mass balance in nutrient management. This principle embraces the concept that nutrients, either in solution or within the plants, should be added based on the needs of the plants for optimum biomass production and harvest index. Three concentrations of nitrogen/potassium nutrient solutions were used as refill solutions. Foliage production was found to exceed storage root production; therefore, it was concluded that more work is needed in this field.
22) *Response of Peanut [Arachis Hypogaea] to Increasing Levels of Blue Light*, paper 2001-01-2275, also presented by Desmond Mortley/Tuskegee University, discusses the sensitivity of peanut plants to increasing percentages of blue light. The cultivar "Georgia Red" was studied to determine the effect of blue photon variation on stem elongation and biomass yield. The harvest index was found to decline linearly with increased blue light. As plant height is important in ALS, the findings of "Georgia Red's" reduced stem elongation with increased blue light was felt to be beneficial to ALS crop growth studies.

23) *Actual Knowledge of Martian Environment and Associated Thermal Control and Life Support Solutions for the Future*, paper 2001-01-2283, contains information on the Martian atmosphere composition and thermal environment. The paper discusses the solar flux seen at the Martian surface and the effects of dust on the thermal environment. This information is relevant to thermal control, environmental control, and spaceship design.
24) Numerous presentations were given at the conference regarding ground-based integrated life support testing, often as it related to BIO-Plex. Topics focused on dynamic modeling, biomass production systems, food processing systems, composting, and thermal control. Many of these are discussed in more detail in highlights 25 through 30.
25) *Bioregenerative Planetary Life Support Systems Test Complex (BIO-Plex): Progress To Date*, paper 2001-01-2317, presented by D. Henninger/JSC on behalf of Terry O. Tri/JSC, provides an overview of the progress made in the testing of BIO-Plex facilities prior to the deferral of BIO-Plex activities. The current layout of the facility is described as well as proposed future chamber additions to BIO-Plex. A timeline is provided that addresses a series of proposed test missions lasting 120 days, 240 days, and 540 days. The ability of BIO-Plex to support air revitalization, water recovery, and biomass production as they relate to each test mission is discussed.
26) A dynamic flow model using MATLAB/Simulink© simulation results was presented by Cory Finn/NASA Ames Research Center. Sizing and operation issues relating to the sizing of the Air Revitalization System is discussed in a paper entitled *Dynamic Model of the BIO-Plex Air Revitalization System*, paper 2001-01-2318. The role of the biomass production chamber and CO_2/O_2 setpoints is discussed in detail with scenarios ranging from unstaged "cold start" crop growth to staged crop plantings. The role of the Oxygen Generation System is discussed in conjunction with the simulation of a high level of crop growth. Solid waste treatment is addressed from the standpoint of the increased storage requirement due to inedible biomass as well as the possible necessity to provide CO_2 to the biomass chamber via incineration of feces.
27) Design work for the BIO-Plex biomass production chamber (BPC) was presented by Daniel J. Barta/JSC in paper 2001-01-2319, *Preliminary Designs of the Biomass Production System for the Bioregenerative Planetary Life Support Systems Test Complex*. This paper is based on data presented in the August, 2000 preliminary design review. The BIO-Plex BPC layout was presented along with a detailed description of the BPC center shelf design, lighting requirements, and mechanized propagation, seeding, and harvesting of the crops grown within the chamber.
28) Development of a Transit Food System and a Planetary Food System is discussed in *Bioregenerative Planetary Life Support Systems Test Complex (BIO-Plex) Food Processing System; A Dual Task Approach*, paper 2001-01-2321, presented by Michele Perchonok/National Space Biomedical Research Institute. The use of prepackaged food supplies as well as freshly grown crops has been considered under both microgravity and hypogravity conditions. Constraints considered within the food system design are the minimization of power, mass, water usage, volume, and waste production. Also considered are the maximization of safety, acceptability, and nutritional content of the food supplies. Of primary importance is the development of packaging that provides a 3-5 year shelf-life of the food products.
29) *Food Processing Systems for Long-Term Planetary Missions: The Design of a Prototype for Soy Processing*, paper 2001-01-2322, describes the attributes of the prototype STOW (soymilk, tofu, okara, and whey) processor as a means to process raw, unhulled soybeans grown in BIO-Plex during a Martian surface stay. The constraints of safety, palatability,

and nutritional quality, as well as space limitations, water and energy limitations, wastage, and crew time are addressed. Photographic examples of food products generated from the existing STOW prototype were provided by Dr. Perchonok/National Space Biomedical Research Institute.

30) *Modeling of a Composting System Within BIO-Plex*, paper 2001-01-2323, describes the development of a dynamic mass balance model using MATLAB/Simulink© to model and analyze a BIO-Plex composting system that is inclusive of feces, edible and inedible food wastes, and paper trash.
31) Many presentations were given regarding the International Space Station (ISS) Thermal Control, including *Development of the Internal Thermal Control System (ITCS) for International Space Station (ISS)*, paper 2001-01-2332, and *International Space Station Internal Thermal Control System Cold Plate/Fluid Stability Test Setup and Preliminary Test Results*, paper 2001-01-2334.
32) Alan Drysdale/Boeing/KSC presented a paper entitled *Life Support Equivalent System Mass Predictions for the Mars Dual Lander Reference Mission*, paper 2001-01-2358. This paper discusses the equivalent system mass (ESM) approach used by NASA to identify costs associated with mass, power, volume, cooling, and crew time mission requirements of ALS subsystems on an equivalent mass basis. An ALS "straw man" architecture was presented for the Mars Dual Lander Reference Mission. Dr. Drysdale proposes that computation of ESM at the system level will identify the most costly subsystems and can be used to assist in the determination of the most optimum life support system configuration.
33) *The Cost and Equivalent System Mass of Space Crew Time*, paper 2001-01-2359, presented by Harry Jones/NASA Ames Research Center, discusses the theory that equivalent system mass (ESM) crew time may depend on the total mission mass or the mass of consumables. This theory embraces the concept that the "price" of crew time should be based upon the amount of time required to perform a specific task. A detailed explanation is offered with regard to the optimization of the mission workload through the cost of crew time. Previous computation of ESM crew time has been based upon the quotient of the ESM of the life support system and the number of available crew work hours.
34) Julie Levri/NASA Ames Research Center gave a presentation (*Practical Scheduling Considerations of Waste Heat Reuse for a Mars Mission Advanced Life Support System*, paper 2001-01-2363) that discussed how to efficiently match waste heat generators to heat consumers during a Mars mission. By reusing heat that would ordinarily be rejected, her technique reduces not only the overall power generation needs but also the size of the heat rejection equipment required.
35) Andrew Hensley, a mechanical engineering graduate student at Texas A&M University, discussed SINDA/FLUINT and Thermal Desktop modeling of the ISS in *Shadowing Studies of External Sites on the International Space Station*, paper 2001-02-2430. His modeling considered a variety of beta angles to confirm that shadowing from the space station will have a major effect on commercial payloads.
36) *Test of Development Condensing Heat Exchanger to Characterize Particulates and Metals Concentration in ISS Condensate*, paper 2001-01-2312, discussed the amount of zinc and silver that will dissolve into the water condensate from the biocide coating. This has relevance to BIO-Plex: prior to BIO-Plex deferment, a discussion was ongoing to ascertain whether such a coating was required on the BIO-Plex condensing heat exchangers, and how much of an effect it would have on the condensate.
37) *International Space Station Node 3 Environmental Control and Life Support System Status*, paper 2001-01-2387, gives an overview of the space station ECLSS.

38) Operation of the volatile removal assembly (VRA) aboard the ISS was discussed in *Investigation into the Performance Membrane Separator Technologies used in the International Space Station Regenerative Life Support Systems: Results and Lessons Learned*, paper 2001-01-2354.
39) *Life Support Trade Studies Involving Plants*, paper 2001-01-2362, presented by Alan Drysdale/Boeing/KSC, discusses an Equivalent System Mass (ESM) approach to the benefits of plant growth in space versus food shipment from Earth. The growth of salad crops are discussed based on the length of time between resupply of fresh foods during a Mars surface stay.
40) Prepackaged food system options for a Mars surface stay, based on the Shuttle Training Menu and the ISS Assembly Complete food systems, are evaluated in *Food System Trade Study for an Early Mars Mission*, paper 2001-01-2364. Presented by Julie Levri/NASA Ames Research Center, this paper uses equivalent system mass (ESM) to evaluate five food system options in terms of mass, power, volume, cooling, and crew time requirements. The study was prepared based on the assumption that little fresh crop growth would be available during missions and that the bulk of the astronauts' diet would consist of prepackaged food. The roles of the food, biomass production, air revitalization, water recovery, and solid waste processing ALS subsystems were addressed, as well as the extravehicular activity and human accommodation external interfaces.
41) *Predictive Techniques for Spacecraft Cabin Air Quality Control*, paper 2001-01-2398, discusses a modeling approach used to predict trace chemical contaminant (TCC) loads onboard ISS spacecraft. This approach is based on air quality standard limitations known as Spacecraft Maximum Allowable Concentrations (SMACs) and the Toxic Hazard Index (T-value). The model calculates predicted TCC loads and the overall T-value for the cabin air quality based primarily on equipment offgassing and human metabolism but solves a cabin mass balance for all TCCs. Predicted values have been compared to measured data and have been found to be of a conservative nature. The measured data are similar to those described in paper 2001-01-2396, *Toxicological Assessment of the International Space Station Atmosphere*. This paper describes the formaldehyde badges and grab sample canisters used to sample the air quality aboard four ISS flights. It also describes crew reports and analytical data from the flights relating to the presence/absence of strong odors and presence/absence of adverse air pollution effects on the health of the crew.
42) *A Process to Evaluate Advanced Technologies for Future NASA Needs*, paper 2001-01-2399, addresses the technology selection process and may be of help to engineers trying to determine which technologies to pursue. According to the author, the selection process begins with a set of well-defined requirements, followed by a "call for technologies" and the establishment of an expert panel. Finally, the expert panel uses an evaluation process that compares different technologies using a standard set of criteria.
43) *Spreadsheet Analysis for Early Phase Thermal Design*, paper 2001-01-2436, discussed the ThermXL tool. This tool is a Microsoft Excel "add-in" that performs simple and quick thermal analyses on small systems (less than 50 nodes). ThermXL appeared to serve the same function as SINDA/FLUINT.
44) One major issue facing major integrated testing, such as in BIO-Plex, is power management. *An Electrical Power Planning Simulation and Graphical User Interface for an Advanced Space Habitat Life Support System*, paper 2001-01-2377, describes a software tool, BIO-Sim, that was designed to help track power consuming devices and their schedule of use. During testing of integrated systems, this tool would aid in the planning of operations to ensure that adequate power resources are available and to track average power and total energy used.

45) In the interest of planetary protection, a hydrogen peroxide sterilization process for planetary spacecraft has been tested by the Jet Propulsion Laboratory of the California Institute of Technology. Presented by Naresh Rohatgi in paper 2001-01-2411, *Development of Vapor Phase Hydrogen Peroxide Sterilization Process for Spacecraft Applications,* this paper discusses the issues of the efficacy of the H_2O_2 sterilization process currently in progress, the diffusion of H_2O_2 under the process in hard-to-reach places, the compatibility of materials and components, and the development of a technique to isolate sensitive components from H_2O_2 vapor. Five sterilization phases are discussed: Vacuum phase, H_2O_2 injection, H_2O_2 diffusion stage, plasma (for the breakdown of H_2O_2 into water and oxygen), and the venting phase, where sterilized filtered air enters the test chamber.
46) Paper 2001-01-2172, *Commercial Space Habitation*, discusses the development of the commercial habitation business and lists expected hardware requirements for an orbiting hotel.
47) A process to recover nutrients from solid wastes was discussed in paper 2001-01-2205, *Bioprocessing to Recover Crop Nutrients from ALS Solid Wastes: A Two-Stage Solid-Liquid Separation System for Removal of Particulates from Bioreactor 'Broth'*. A two-stage filtration process is used, and different filtration membranes are evaluated.
48) Paper 2001-01-2206, *Microbial Requirements for Optimal Surfactant Degradation in a Denitrifying Fixed-Bed Bioreactor,* looks at a study to determine the microbial requirements of the Immobilized Microbe Microgravity Water Processing System (IMMWPS).
49) Nutrient recycling and waste recovery were discussed in paper 2001-01-2208, *Bioprocessing to Recover Crop Nutrients from Advanced Life Support Solid Wastes: Improving Rapid Biological Processing of ALS Inedible Crop Residues*. This has application in any long-duration space mission in which a reliance on expendables is unwanted.
50) K. Pickering/JSC discusses the results of a test in which wastewater streams from different crew activities could be converted into potable water in paper 2001-01-2210, *Early Results of an Integrated Water Recovery System Test*. This test was conducted at JSC by the Crew and Thermal Systems Division.
51) Paper 2001-01-2211, *Integration of Composting, Plant Growth and Biofiltration for Advanced Life Support Systems,* discusses the integration of composting technology with ALS plant growth scenarios.
52) One possible technology for waste processing is incineration. Paper 2001-01-2249, *Design and Construction of a Pilot Scale System to Remove Pollutants from an Incinerator Effluent,* discusses a system to remove pollutants found in the effluent of an incinerator.
53) Cory Finn/NASA Ames Research Center discussed *Advanced Control Techniques for Efficient and Robust Operations of Advanced Life Support Systems,* in paper 2001-01-2298. Using mass balance equations and economic models, she and her colleagues have developed a tool for developing control strategies for regenerative life support systems.
54) Paper 2001-01-2303, *Modeling of Photosynthesis in Soybean Crops Using Artificial Neural Networks,* discusses the development of a model that characterizes soybean photosynthesis. It takes into account many factors that will influence photosynthesis: carbon dioxide level, light intensity, temperature, and relative humidity.
55) *A Prototype Pyrolyzer for Solid Waste Resource Recovery in Space,* paper no. 2001-01-2349, discusses a two-stage reactor system for processing waste. This is a high-temperature (up to 1100°C) process that will gasify the wastes.
56) Paper 2001-01-2357, *Development of a Membrane Based Gas Liquid Separator for the Space Station Water Processor,* discusses a passive gas-liquid separator to extract free gas from the two-phase inlet mixture. This is in response to a crew request for gas-free drinking

water at 37.8°C.

57) *BIO-Plex Thermal Control System Design*, paper 2001-01-2324, gives an overview and status of the BIO-Plex thermal control system.
58) *Thermal Analysis of Compressible Gaseous Nitrogen Flow of X-38 Pressure Control System for First Mission Phase*, paper 2001-01-2433, discusses the development of a computer model that determined whether heaters would be needed on the X-38 nitrogen storage tanks.
59) *Estimating Plant Growth Area with the Biomass Production Chamber Sizing Model*, paper 2001-01-2320, discusses the development of a computer model that estimates the amount of plant growth area and gas exchange rates required within a biomass production chamber.
60) *Advanced Life Support Sizing Analysis Tool (ALSSAT) Using Microsoft® Excel*, paper 2001-01-2304, discussed the development and use of the ALSSAT.
61) *A Trade Study on Sabatier CO_2 Reduction Subsystem for Advanced Missions*, paper 2001-01-2293, written by Frank Jeng/LMSO and Dr. Chin Lin/JSC, discusses the results of a trade study on the Sabatier CO_2 reduction system. This paper was presented by Richard Chu/HEI on behalf of Frank Jeng/LMSO.

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2. *31st International Conference on Environmental Systems Book of Abstracts*, Society of Automotive Engineers, Inc., Warrendale, PA, USA.
3. *Proceedings of the 31st International Conference on Environmental Systems (ICES)* (compact disk), Society of Automotive Engineers, Inc., July 9-12, 2001.

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